10/16/07
Michael J. Longo

Measurement of Temperature Variation of Time Delay for Twist-and-Flat Cable

I was puzzled by Carl's results for the change of transit time in the TOF twist and flat cables with temperature. He found a variation of 2.2×10^{-3} per deg C.

The expansion coefficient of copper (the conductor) is 1.7×10^{-5} per deg C. It's possible that the copper stretches or contracts in length when the dielectric changes length. The coefficient for PTFE, which I believe is the dielectric, is about 1×10^{-4}, still 22 x smaller than Carl's "coefficient". The velocity goes as 1/sqrt(K), the dielectric constant. That's a slow dependence, and I'm almost sure K is not significantly temperature dependent.

To settle the matter, I found a 100-foot long piece of twist and flat cable. I looked at the back and forth transit time, which was about 340 ns, using a scope and pulser. The transit time was then observed when the temperature was cycled between room temperature (about 21°C) and H_2O ice (about 2°C). This was accomplished by covering the coiled cable with ground ice.

For a temperature change of about ±18 deg, as measured with a thermocouple in the coil, I saw a reproducible change in the transit time of ±2 ns with an accuracy of about 0.2 ns. This corresponds to a coefficient of 3×10^{-4} per deg C which is a factor ~7 smaller than Carl's measurement.

The observed variations of the TOFs are ~5 ns in 200 ns over periods of a day or so. If we assume this corresponds to temperature variations ~20° C, the coefficient would be $\sim 1.2 \times 10^{-3}$. This is about 4 times larger than the coefficient I measured.

I conclude that the TOF variations are not directly due to temperature changes in the cable delays. They must be due to some temperature or other effect on the electronics. The specifications for the LeCroy 2229 TDC are "typically" a coefficient of ±0.02% of full scale per deg C. I believe full scale is about 100 ns, so this corresponds to 0.02 ns per deg C. If the specs are to be believed, this is too small to account for 5 ns variations over a day or so.

My scenario for explaining the temperature drifts in the TOF is that the pulses from the 4416 Discriminators are attenuated by the twist-and-flat cables and are marginally driving the Stop of the 2229 TDCs. The attenuation of the ECL pulses in the cable is about a factor of 2 and the rise time is seriously degraded. Thus the temperature effects may be due to small changes in the thresholds of the Stop inputs of the TDCs with their temperature or power supply voltages. In the LeCroy manual for the 2229 TDC, LeCroy notes that the Start and Stop input threshold levels are affected by temperature, voltage, or time variations. They suggest that care be taken to use identical pulses (amplitude and rise time) for the Start and Stop inputs, so that these drifts will cancel out.

10/16/07
Michael J. Longo

It is essential to understand the underlying cause of the TOF drifts if we are to make the TOF data usable. If this scenario is correct, the important temperature changes are occurring at the racks, rather than along the cables. Unfortunately this doesn't make the job any easier, but it might point us to a more appropriate strategy to understand it.